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ELECTRICITY REGULATION AND ECONOMIC GROWTH

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**Energy Sustainability**

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## ELECTRICITY REGULATION AND ECONOMIC GROWTH

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**ABSTRACT:** The main objective of this paper is to analyse the effect of electricity regulation on economic growth. Although the relationship between electricity consumption and economic growth has been extensively analysed in the empirical literature, this framework has not been used to estimate the effect of electricity regulation on economic growth. Understanding this effect is essential for the assessment of regulatory policy. Specifically, we assess the effects of two major regulations, renewable energy promotion costs and network cost, on electricity consumption and growth. A dataset for the period 2007-2013 and 22 European countries was compiled based on CEER reports and EUROSTAT databases. The results of the empirical analysis show that the two regulation instruments have a negative effect on electricity consumption and economic growth and provide estimates of their effects on growth in quantitative terms.

**Keywords:** Electricity regulation, network costs, renewable energy, GDP

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## 1. INTRODUCTION

In the last decade it has become evident that the energy sector is in a turning point, a new model is required to face the challenges of the upcoming years. The required transformation of the traditional energy model, especially with regard to the environmental effects, has led to an inevitable and profound regulatory reform. From a regulatory perspective, the energy sector has witnessed a high level of activity at the European level. Three consecutive packages were adopted aiming at harmonising and liberalising the European Union (EU) internal energy market. In addition, the climate and energy package set ambitious targets for 2020 in terms of emissions reduction, penetration of renewables and energy efficiency. Climate and energy as an integrated policy within the EU has led to the trilemma of targets: competitiveness, sustainability, and security of supply. More recently, the European Commission has defined the 2050 roadmap and the 2030 targets as an intermediate step in energy and climate policy to achieve sustainable economic growth.

Unfortunately, the objectives pursued by the climate and energy policy of the EU – environmental sustainability, security of supply and competitiveness- are difficult to achieve simultaneously and even more if they are supported on market forces only. Therefore, priorities need to be set. When the energy policy objectives are analysed in detail, it becomes apparent that the environmental dimension has played an important role. Nevertheless, the economic crisis and its undesirable effects on the capacity of European economies to grow and create wealth, have increased the attention on competitiveness as one of the main concerns in the policy agenda. It is fundamental for industrial development and economic growth that European firms preserve or improve its competitiveness. Within this context -and having in mind the other energy policy objectives, since firms must compete in difficult environments-, the basic question is on the role of energy in the operating cost and in the competitiveness.

The increasing concern in Europe about the recent evolution of energy costs and prices and its impact on the industrial competitiveness is observable in the 2014 EU Communication 'For a European Industrial Renaissance'. Every day it becomes more important to secure an affordable access to energy and raw materials, since these are an important part of the costs in many industries. In so far as the evolution of energy costs negatively influences the competitiveness of energy intensive industries, it is fundamental to avoid disproportionate increases of those costs as a consequence of taxes, levies or other instruments introduced by Member States to enforce different policies. This is essential to guarantee a good cost-effectiveness relation and contribute to improve EU competitiveness. Therefore, the assumption of the upcoming

objectives must follow an approach of costs effectiveness -affordable and competitive-, ensuring the security of supply and sustainability, while taking into account the current economic and political context.

The main objective of this paper is to analyse the effect of electricity regulation on economic growth. Understanding this effect is deemed essential for the assessment of regulatory policy. Specifically, we assess the effects of two major regulations, renewable energy promotion costs and industrial network cost, on electricity consumption and GDP. In this analysis we assume that this impact takes place through the influence of regulation on electricity consumption.

To carry out the empirical estimation, a database for the period 2007-2013 and 22 European countries has been compiled based on EUROSTAT database and Council of European Energy Regulators (CEER) reports. The information for 22 countries and 7 years allows us to have an appropriate panel of data. The contribution of this paper to the literature is as follows. First, instead of analysing the effects of regulation on economic growth directly, we use a system of two equations to take into account the fact that electricity regulation potentially affects economic growth through its impact on electricity consumption. This procedure helps to improve our understanding of the mechanisms regarding the effects of electricity regulation on growth. Second, many papers focus on only one specific instrument. Instead, we consider the two main regulatory instruments, the renewable energy promotion costs and the networks costs and therefore we can compare their effects. Third, to include both instruments has required the construction of a novel and comparable measure of renewable promotion costs for 22 European countries.

The rest of the paper is organised as follows. Section 2 provides the background on the link we explore latter in the empirical exercise between regulation, electricity consumption and economic growth. In Section 3 the model, variables and methods are detailed described. Section 4 informs and discuss the empirical analysis results. Finally, Section 5 holds the conclusions and policy implication derived from the performed analysis.

## 2. BACKGROUND: REGULATION, ELECTRICITY CONSUMPTION AND ECONOMIC GROWTH

Despite its relevance for the analysis of regulatory policies, the academic literature has devoted little attention to the relationship between electricity regulation and economic growth. This is mainly attributable to the fact that this relationship is not a direct one, but rather it is mediated

through the effect that regulation has on the consumption of electric energy. The mechanism at work in this relationship is the following; electricity is an economic factor of great relevance since it is a key input in the modern production process, having its consumption a significant impact on a company's production costs and, hence, on economic growth. Next, we provide background and fundamentals for our modelling approach based, first, on the link between regulation and electricity consumption (emphasising on the conceptual framework), and second, on the relation between electricity consumption and economic growth.

## 2.1. Regulation and electricity consumption

This research starts from the assumption that the price system is a useful mechanism to transmit relevant information having an impact on consumers behaviour, also in the European context. Whether a depletion of an existing resource, an increasing scarcity of a non-renewable energy or an arbitrage opportunity in some market, all the relevant information is usually transmitted through the price, through variations in price levels that make agents react to the changes by changing, for instance, their consumption.

Among the various economic activities, the electricity sector is characterised for being one of the most highly regulated sectors. In the framework of liberalisation, being pushed forward in January 1997 with the publication of EC Directive 96/92/EC of 19 December, the regulatory changes affecting the electricity sector have been especially intense and have had an enormous impact on the structure of the sector and its business agents, as well as on the functioning of the electricity market itself.

Under this process, the regulatory function appears as a key element, being responsible for the definition of the framework that guarantees the correct technical management of the power system, the coordination of the networks and the transparency of access conditions for all the agents participating in the power market. In other words, in this process of liberalisation competition and regulation represent the two sides of the same coin. Real competition in power markets cannot be fully achieved without ensuring non-discriminatory network access and market functioning at the wholesale and retail levels. Economic regulation must guarantee the recovery of all regulated costs in order to ensure the economic viability of the power system. In this context, energy regulation has a significant economic impact, which has to be considered ex-ante when designing energy policy initiatives.

Evaluating the economic impact of the regulation of the electricity sector and of the changes in these regulations is a complex task. The assessment and measurement of the impact of the

reform processes and regulatory changes have been analysed in the relevant literature with different general approaches.

The first is a macroeconomic approach focusing on the analysis of regulatory policies and their impact within the framework of general equilibrium theory (Chisari and Estache, 1999). Contributors using this approach constructed general equilibrium models in an attempt to capture first- and second-order effects to establish, identify and quantify transmission mechanisms and the overall effects of a specific regulatory policy or measure on economic growth, through the modelling of the behaviour of economic agents. The analysis of the impact of regulatory policies with general equilibrium models is intuitively attractive as it allows the quantification of, both, direct and indirect economic effects. However, these models are characterised by an enormous complexity and the constraints placed on any formulation, implementation and description, given the need to simplify the hypotheses governing the transmission mechanisms. This limitation warns against their use when the aim is to analyse the impact of specific actions in the regulatory domain.

The second approach has involved the quantitative evaluation of a country's regulatory framework. This provides a better understanding of the risks, particularly the regulatory ones. Such an evaluation of the regulatory framework is useful in a number of ways: it enables comparisons to be made; it identifies possible improvements; and it facilitates the evaluation of the impact of implementing new measures. The evaluation is not without its difficulties (Becker, 2009) since it requires access to measurable parameters that allow an analysis of their evolution over time as well as a comparative analysis of regulatory frameworks.

Given that all regulatory actions seek to achieve a significant improvement in the provision of electric power supply, a third set of studies has attempted to assess the effects of regulatory changes based on the measurement and evaluation of outcomes – the so-called performance metrics approach – in terms of price, accessibility, quality and efficiency in the provision of the service (Cubbin and Stern, 2006; Pollitt, 2009). This approach has been widely used in academic studies for evaluating the impact of regulatory changes based on the results obtained in terms of pricing, consumption, investment, service quality or the evolution in greenhouse gases emissions, among others.

Agreed the limitations of the first two approaches, the general framework provided by the third approach has been used in this paper. This framework is deemed suitable to address the issues raised in the introduction as well as to capture the flexibility required by the diversity of

contexts in which the effect of electricity regulation is to be assessed. Several regulatory variables have been considered as key drivers of electricity consumption, the focus of this paper is on the two specific regulated components of the electricity retail price. This choice is motivated by their weight in retail electricity price, and consequently, the potential relevance of their impact on electricity consumption. On average for the 22 European countries included in our sample, during the period 2007-2013 the promotion costs related to the support for RES-E and the network costs represented respectively 11% and 23% of the retail price faced by industrial consumers. In the context of this study, given that the mechanism through which regulation affect consumption is via regulated components of retail price, a negative relation is expected between the regulatory variables and electricity consumption.

## 2.2. Electricity consumption and growth

The relationship between electricity consumption and economic growth has been extensively analysed in the empirical literature. Understanding the links and the direction of causality between these two variables has important implications for the design of energy and environmental policies.

As recent reviews of the literature show (Payne, 2010; Ozturk, 2010), in spite of the huge number of contributions to the analysis of the relationship between electricity consumption and growth there is not a consensus neither with respect to the magnitude of the effects nor the direction of that effect. This lack of consensus in the empirical literature is due to the differences in energy consumption patterns, different countries characteristics regarding their stage of development and institutional aspects, heterogeneity in climate conditions and the time period chosen for the studies (Payne, 2010; Ozturk, 2010).

The multiplicity of results gives support to different hypotheses. More specifically, this relationship can be synthesized into four testable hypotheses (Payne, 2010):

The first one, in the context of a Granger-causality approach, is “the growth hypothesis”. This hypothesis is based on the idea that energy, together with labour and capital, is a main driver of economic growth. It is supported if an increase in energy consumption causes an increase in the real gross domestic product (GDP). A main policy implication would be that energy conservation policies could have a negative effect on economic growth

On the other hand, “the conservation hypothesis” is supported if an increase in real GDP causes an increase in energy consumption. This would imply that energy conservation policies, such as



greenhouse emission reductions, efficiency improvement measures or management policies whose aim is to reduce energy consumption would not adversely affect real GDP.

Regarding the third theory, “the neutrality hypothesis”, the absence of Granger-causality is assumed. Energy consumption is regarded as a small component of real GDP or it is not correlated with GDP and therefore its change should not have a significant impact on economic growth. In this case, it is expected that energy policies do not affect economic growth.

The last one, “the feedback hypothesis”, suggests that energy consumption and real GDP are jointly determined and may serve as complements to one another. This approach is supported statistically when there is evidence of bi-directional Granger-causality. Again, policies that foster the efficiency in energy consumption may not adversely affect real GDP.

To sum up, the literature review suggests that, whereas a negative effect of energy regulation on electricity consumption can be expected, the final effect on economic growth is not conclusive and it is a matter of empirical analysis. The surveys of the empirical literature on the electricity consumption-growth nexus have emphasized the convenience to use multivariate models and to support the empirical analysis on well-established theoretical frameworks to include all the relevant control variables. Therefore, our empirical estimations are based on the theory of economic growth (Solow, 1956; Romer, 1990) that provides a formal framework for the analysis of the determinants of growth and the ensuing effects on electricity consumption.

### 3. MODEL, VARIABLES AND METHODS

The approach to estimate the impacts of electricity regulation on growth is based on the theory of economic growth and on the relationship between electricity consumption and growth. In the framework of growth theory, the contribution of production factors to economic growth is analysed. In our empirical analysis it is assumed, as has been pointed out above, that electricity regulation potentially affects economic growth through its impact on electricity consumption.

Therefore, we use a system of two equations that is estimated in two stages. The first stage of the econometric model captures the impact of electricity regulation on electricity consumption, controlling for the other observable factors that affect this consumption (Eq. 1). In particular, our purpose is to analyse the effects of renewable energy promotion costs and industrial networks costs. The second stage captures the impact of electricity consumption (the estimated

value from the first stage) on economic growth, controlling for the other observable factors of production (capital and employment) which have a direct impact on economic growth (Eq. 2).

$$\left\{ \begin{array}{l} Econs_{it} = \delta_0 + \delta_1 Econs_{it-1} + \delta_2 RPC_{it} + \delta_3 NC_{it} + \delta_3 EC_{it} + \delta_4 IS_{it} + \delta_{it} + \varepsilon_{31it} \quad (1) \\ LogGDP_{it} = \gamma_0 + \gamma_1 Log\widehat{Econs}_{it} + \gamma_2 LogK_{it} + \gamma_3 LogEMP_{it} + \gamma_4 PT_{it} + \gamma_{it} + \varepsilon_{32it} \quad (2) \end{array} \right.$$

where a full description of the variables and its sources are provided in Table 1. In order to carry out the empirical estimation, a dataset for the period 2007-2013 and 22 European countries has been compiled based on EUROSTAT database and CEER reports. The information for 22 countries and 7 years allows us to have an appropriate panel of data in order to apply panel-data models, which have substantial advantages with respect to estimation techniques which use cross-section data, including the capacity to control for individual heterogeneity, a greater degree of freedom and a greater variability.

- INSERT TABLE 1 AROUND HERE-

Special mention deserves the regulatory variable capturing the promotion costs related to the support for RES-E, Renewable Promotion Costs (RPC). Unlike all other variables used in this analysis, the information required to identify the impact of renewable electricity support costs is not directly available in a standardized public or private database. This novel variable, based on the information provided by the Council of European Energy Regulators reports (CEER 2011, 2013, 2015), was built as follows. First, the total expenditures on RES-E promotion were calculated as the product of the RES-E weighted average support level by technology (from CEER reports) multiplied by the overall RES-E production (from EUROSTAT). Then, the Renewable Promotion Cost (RPC) was calculated as the ratio between the total expenditure on RES-E promotion and the total electricity consumption (from EUROSTAT). Therefore, the resulting variable is measured on €/MWh units. This variable allows capturing the degree of these regulated costs taking into account the size of the electricity system (in terms of MWh of electricity generation), which facilitates cross-country comparisons. Table 2 provides the summary of the descriptive statistics for this and the other variables used in this study.

- INSERT TABLE 2 AROUND HERE-

Table 3 contains the correlation matrix which provides relevant information on the relation between the variables included in our model. This correlation matrix had helped us to reject the presence of multicollineality which could arise if there was a high correlation between the explanatory variables. Therefore, it has been useful to develop the specification of the model to perform the empirical analysis.

- INSERT TABLE 3 AROUND HERE-

Before we carry out the empirical estimation, we test the nature of the evolution of the relationship between the two main variables (*GDP* and *Econs*) over time. Regarding this relationship, two or more cross-sectional time series are cointegrated if they share a common stochastic drift, and only integrated variables can be cointegrated. Therefore we need to test for the integration of the variables before proceeding with cointegration. We performed two tests, the augmented Dickey-Fuller (ADF) test (Dickey and Fuller, 1979) and the Phillips–Perron (PP) test (Phillips–Perron, 1988), both under the null hypothesis of a unit root (integration of first order). The results for both tests confirmed that the series were not integrated in levels and, hence, that it was not necessary to test for cointegration (see Table 4). This means that the variables might depend on themselves (with a coefficient lower than one) and may affect each other but they do not move together within the period for the countries being considered. Moreover, these results confirm that we can use the variables either in levels or logarithms. The last option (logarithmical) is deemed the appropriate functional form in the growth equation based in a Coob-Douglas production function.

- INSERT TABLE 4 AROUND HERE-

The empirical estimation is performed using the aforementioned database through the implementation of the following panel data econometric techniques. In the first stage, the consumption equation (Eq. 1) is estimated with the Arellano-Bond method for dynamic panel data. This allow us to avoid the potential bias coming from the endogeneity which generally features a dynamic process. The estimated values of electricity consumption, capturing the estimated effects of regulation (RPC and NC), are recovered and stored. In the second stage, the estimated values of the first stage are introduced into the growth equation (Eq. 2). It is then estimated with fixed effect panel data techniques.

#### 4. RESULTS AND DISCUSSION

Tables 5 and 6 show the results of the estimations of the two equations used to assess the effects of the two regulations, renewable energy promotion costs and industrial network cost, on electricity consumption and GDP.

- INSERT TABLES 5 & 6 AROUND HERE-

The results for the effects of the two regulations on electricity consumption and GDP show the expected negative sign, are statistically significant and their magnitudes are reasonable. In both cases we are assuming, as we explained in the description of the model, that the impact on GDP takes place through the effects on electricity consumption. Renewable promotion costs and network costs caused an increase in the electricity prices that, as our estimations show, have a negative effect on electricity consumption. Our results of the estimation of the growth equation support the “growth hypothesis” regarding the relation between electricity consumption and growth. This hypothesis is based on the assumption that energy, together with labour and capital, is a factor of production and a driver of economic growth. Therefore, the reduction of electricity consumption negatively affects economic growth with a decrease in GDP levels.

These estimations allow therefore assessing these two regulatory instruments and having a proper estimation of their quantitative effects on the levels of GDP. Nevertheless, our analysis focuses only on the direct effects of regulation on electricity consumption and GDP and does not consider other possible, indirect effects that, for instance, the promotion of renewable energies may have on technological innovation and potentially on economic growth.

The estimation of the elasticities regarding the effects of renewable energy promotion costs presented in Table 7 shows that an increase of 1% in these costs leads to a decrease of 0.03% in electricity consumption and a reduction of 0.006% in the GDP level which, in absolute terms, means a 28.6M€ decrease. Departing from the assumption that there are not any additional regulatory changes during the period, the long-run elasticities are, as expected lower, although only slightly, than the short-term elasticities.

- INSERT TABLE 7 AROUND HERE-

The parameter of the estimations of the other regulatory variable, the network cost, are also negative (see Table 8). The estimations of the elasticities show that an increase of 1% in these costs leads to a decrease of 0.06% in electricity consumption and of 0.01% in the GDP level. In absolute terms this means a reduction of 55.8M€. Again, long-term elasticities are slightly lower than the short-term elasticities.

- INSERT TABLE 8 AROUND HERE-

The comparison of both regulatory instruments shows that in relative terms the quantitative effects on the GDP are higher for network costs than for renewable promotion costs. Nevertheless, it is necessary to be cautious in this comparison because they are significantly different in monetary terms, with the effects from a 1% increase in the network costs being higher than from a 1% increase in the renewables promotion costs.

Besides, while a 1% increase in the network costs is in average equivalent to 0.29€/MWh, the same increase in the renewables promotion costs is in average equivalent to 0.14€/MWh. Therefore, when comparing the results from the two regulated variables, these are in line with the expectations, given the estimated elasticities and their average values.

Finally, the results corresponding to the control variables included in both equations, needed to avoid omitted variables and to ensure that we obtain causal relationships between regulatory variables and growth, are all statistically significant and show the expected signs. In the two estimations, corresponding to renewable promotion costs and network costs, the variables of the growth equation (employment, capital and productivity trend) have positive values. In addition, in the electricity consumption a greater participation of energy intensive sectors has a positive effect on electricity consumption while higher energy costs have a negative effect

## 5. CONCLUSIONS AND POLICY IMPLICATIONS

This paper focuses on the effects of electricity regulation on economic growth through its impact on electricity consumption. Although there is an extensive literature analysing the relationship between energy consumption and economic growth, the analysis carried out in this paper introduces several novelties. First, to the best of our knowledge, there is no study that has estimated the specific effects of electricity regulation on economic growth, taking into account their effects on electricity consumption. Second, the paper considers two different instruments to disentangle the effects of regulation on growth: renewable promotion costs and network costs. Third, the renewable promotion costs have been calculated in a standardized way to allow cross-country comparison.

In our analysis we have examined the relationship between electricity regulation and economic growth through the effect that regulation has on the consumption of electricity. In our

estimations we have included other variables, such as the participation of intensive energy sectors or the stock of capital that may mediate this relationship. Nevertheless, in this analysis we have focused specifically on the potential effects of electricity regulation on growth. Although this is an important area, the linkages between electricity regulation and growth are complex and may be affected by different variables, such as investment in capital goods, in innovation, and also by different aspects of the behaviour of firms and consumers that would be convenient to take into account for a comprehensive analysis of these linkages. Despite these limitations, our analysis provides, as pointed out above some novelties and contributes to shed some light on the importance of well- designed electricity regulation and provides some relevant policy implications.

The main results of the analysis show, as expected, that the effect of regulatory cost on electricity consumption is negative. In addition, the final effect on economic growth according to the estimations of the empirical analysis, is also negative. Hence, an increase in the regulated cost leads to a decrease in electricity consumption and to a reduction of GDP. The empirical results support “the growth hypothesis” regarding the relationship between electricity consumption and economic growth.

A main economic implication from these results is that any decrease in electricity consumption, through energy conservation policies, could have a negative effect on economic growth. Nevertheless, it should be pointed out that a reduction in energy consumption may allow for an increase in disposable income to be spent on other products and services positively affecting economic growth. In addition, there are other indirect effects that are not covered by our analysis, so it is necessary to be prudent with our conclusions. It should also be highlighted that this by no means contradicts some recent reports (i.e. IEA, 2016) which suggest that CO<sub>2</sub> emissions are decoupled from economic growth at the world level. Taking into account that a close relationship between electricity consumption and growth is observed, increased decoupling of growth and CO<sub>2</sub> emissions is possible if electricity demand is increasingly covered with RES-E (as suggested by IEA, 2016) or if CCS technologies improve.

In addition, there are regulatory implications, in the sense that any regulation increasing the price of energy will have a negative effect on economic growth. This is an important message for regulators and policy makers involved in the design of regulatory measures affecting prices. It also allows for the use of regulation as a tool to promote economic growth. This is in contrast to what is advocated by some authors in terms of the use of energy taxes on electricity prices as a superior option to promoting energy efficiency (Filipovic et al., 2015).

The effect of the regulatory cost on prices seems to indicate that a revision of the current framework is required. These results reinforce the need to search for market-based regulatory mechanisms that would potentially generate less disruption on prices. This idea is in line with the approach that has been taken by the EC in the most recent energy policy proposal package “Clean energy for all Europeans” (EC, 2016). The Commission sought to transform the energy regulatory framework, emphasising the predominant role that market-based instruments should have in this sector.

The changes implemented during recent years by several European countries in renewable promotion mechanisms are clear examples of an increasing market approach. Moving from Feed-in Tariff to Feed-in Premium or to an auctioning system it is intended to reduce the burden on promotion costs. Another alternative in the case of renewable promotion cost is to avoid financing climate policy through the price of energy, for instance by using funds from the public budget. This would simultaneously profit society from the indirect benefits related to renewable deployment and innovation, while increasing potential growth through a direct effect on electricity prices.

The case of network costs is more complex. Given their natural monopoly features, network costs are traditionally covered through regulated fees. An alternative approach could be to implement innovative solutions allowing for cost reductions, while keeping the competitiveness and investment levels of the companies that are managing the networks, hence, maintaining or increasing the quality of service. For instance, given the economic and environmental costs of electricity losses (Davi-Arderius et al. 2017), measures to decrease losses could reduce the impact on prices related to network cost. In this regard, some options include increasing efficiency in distribution network management through a more active role of DSOs or linking payments to the operator’s ability to introduce innovation -for instance in the deployment of smart grids. In addition, higher network efficiency could be promoted in the transmission level encouraging the cross-border interconnection that is expected to increase price convergence as well as the number of players in the markets. Finally, measures that promote conveniently located Distributed Generation could help to solve grid congestion problems and partially avoid the new investment required.

From the results of the paper, we infer that electricity regulation needs some help to moderate the estimated negative impact that is caused to growth through prices. Policy makers should carefully assess the effects the existing and new regulation can have on growth. Furthermore,

complementary policies that moderate those effects and are able to introduce additional economic incentive should be looked for.

To alleviate the impact on economic growth that lower energy consumption generates a series of policy measures needs to be undertaken to promote energy efficiency. The benefits of energy efficiency policies are multiple affecting everything from macroeconomic performance, environment and industry to energy prices (IEA, 2015). As is stated in the Energy Efficiency Directive proposal recently launched by the European Commission, energy efficiency is considered to trigger growth, job creation and investment (EC, 2016). In this sense, promoting energy efficiency will have positive spillovers on job creation and demand for new appliances and services creating an indirect impact on economic growth. For instance, one recent paper that explores the effects of energy efficiency on economic growth (Bataille & Melton, 2017) shows increases in GDP, employment and welfare. In addition, promoting energy efficiency will allow for the decoupling of economic growth and energy consumption thereby reducing the energy intensity of the economy. Less energy needed per unit of output clearly helps to minimize the negative impact of regulation can have on energy prices and consequently on economic growth. However, governments should be cautious with policy implementation because energy efficiency could jeopardize the expected positive outcome through a rebound effect.

What may be concluded from this paper is that regulatory design should target an efficient allocation of resources, minimizing the effect on prices. Given the positive relationship between electricity consumption and economic growth found in this empirical study, a regulatory policy increasingly reliant on market mechanisms should be designed and implemented, in order to achieve the regional objectives for renewables, energy efficiency and CO<sub>2</sub> reduction. These market mechanisms could be expected to contain regulatory costs to promote renewables -and other costs from policies aiming at energy efficiency or CO<sub>2</sub> mitigation. In the case of networks there is potential for cost containment with the development of innovative regulatory solutions. Nevertheless, any regulatory change should not harm the competitiveness of the sector or its operators, and should not risk the achievement of the energy and environmental targets of European energy policy for 2030. Trade-offs between different goals are likely, however.



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Table 1. The variables. Definitions and sources

Variable	Definition	Source of data
	<b>Equation 1</b>	
Electricity consumption ( <i>Econs</i> ) (dependent variable)	Final energy consumption-electricity (MWh)	Eurostat
Economic growth ( <i>GDP</i> )	Gross domestic product (Billions €)	Eurostat
RES-E promotion costs ( <i>RPC</i> )	RES-E promotion cost (€/MWh)	CEER, Own
Network costs -industrial ( <i>NC</i> )	Transmission and distribution tariffs; transmission and distribution losses; after-sale services; system service costs and meter rental. (€/MWh)	Eurostat
Energy cost ( <i>EC</i> )	Wholesale Cost and Retail Margin for Industrial Consumers	Eurostat
Intensive energy sectors ( <i>IS</i> )	Energy intensive sectors activity (percentage of economic activity) (€/MWh)	Eurostat
	<b>Equation 2</b>	
Economic growth ( <i>GDP</i> ) (dependent variable)	Gross domestic product (Billions €)	Eurostat
Employment ( <i>EMP</i> )	Number of employees. Total economy (1000 persons)	Eurostat
Capital ( <i>K</i> )	Net capital stock, constant prices. Total economy (2010 prices)	Eurostat
Productivity Trend ( <i>PT</i> )	Total productivity trend. Total economy (Index 2010=100)	Eurostat
Electricity consumption ( <i>Econs</i> ) Estimated value	Final energy consumption-electricity (MWh) – Estimated values from first stage	Eurostat

Table 2. Summary statistics

Variable	Observations	Mean	Std. Dev.	Min	Max
<i>GDP</i>	252	463.92	700.00	5.96	2,681.59
<i>PT</i>	224	101.67	3.91	92.41	117.52
<i>K</i>	224	1,271.94	2,177.88	0.74	7,845.83
<i>EMP</i>	224	8,081.55	10,448.78	153.51	42,226.00
<i>Econs</i>	196	100,189,224.49	134,899,234.89	1,707,000.00	532,424,000.00
<i>RPC</i>	154	14.36	10.63	0.50	55.29
<i>EC</i>	180	68.58	27.88	26.90	201.20
<i>NC</i>	180	28.95	10.83	3.50	72.40
<i>IS</i>	196	11.08	6.44	0.00	33.81

Table 3. Correlation Matrix

	<i>GDP</i>	<i>PT</i>	<i>K</i>	<i>EMP</i>	<i>Econs</i>	<i>RPC</i>	<i>EC</i>	<i>NC</i>	<i>IS</i>
<i>GDP</i>	1.000								
<i>PT</i>	-0.092	1.000							
<i>K</i>	0.986	-0.095	1.000						
<i>EMP</i>	0.962	-0.087	0.937	1.000					
<i>Econs</i>	0.986	-0.107	0.963	0.965	1.000				
<i>RPC</i>	0.271	-0.109	0.315	0.250	0.267	1.000			
<i>EC</i>	0.378	-0.286	0.419	0.359	0.337	0.324	1.000		
<i>NC</i>	-0.225	0.184	-0.247	-0.142	-0.235	-0.077	-0.329	1.000	
<i>IS</i>	0.122	-0.068	0.110	0.170	0.171	0.076	0.233	-0.035	1.000

Table 4. Unit root tests for GDP and ECONS

Variable	Statistic	ADF (p-value)	PP (p-value)
<i>GDP</i>	Inverse Chi-squared	2,65628E-09	0,007609123
	Inverse Normal	2,832E-06	0,009314395
	Inverse Logit	7,03071E-08	0,008937038
	Modified inv. chi-squared	4,44089E-16	0,003151377
<i>Econs</i>	Inverse Chi-squared	2,32213E-38	3,63143E-18
	Inverse Normal	1,89146E-14	5,05593E-09
	Inverse Logit	0	4,26326E-14
	Modified inv. chi-squared	0	0

Table 5. Estimations results. First stage: Electricity consumption equation

	<b>Dep. Econs</b>
<b>L.econs</b>	-0.225***
	(0.00880)
<b>GDP</b>	80,457***
	(665.1)
<b>NC</b>	-216,688***
	(22,168)
<b>EC</b>	-51,209***
	(12,946)
<b>IS</b>	136,203***
	(43,550)
<b>RPC</b>	-224,281***
	(19,342)
<b>Constant</b>	8.194e+07***
	(9.277e+06)
<b>Observations</b>	103
<b>Number of id</b>	22
<b>Pseudo R2</b>	0.5474

Table 6. Estimations results. Second stage: Growth equation

	<b>Dep. GDP</b>
<b>IEMP</b>	0.556***
	(0.0472)
<b>IK</b>	0.640***
	(0.0357)
<b><math>\widehat{IEcons}</math></b>	0.192***
	(0.0558)
<b>PT</b>	0.0110***
	(0.000582)
<b>Constant</b>	-7.474***
	(0.896)
<b>Observations</b>	126
<b>Number of id</b>	22
<b>R2</b>	0.935

Table 7. Elasticities of consumption and growth to renewable energy promotion costs

	<b>Consumption</b>	<b>Growth</b>
<b>Short-run Elasticity in %</b>	-0.032	-0.006
<b>Short-run Effect in MWh &amp; M€</b>	-32,207	-28.63
<b>Long-run Elasticity in %</b>	-0.026	-0.005
<b>Long-run Effect in MWh &amp; M€</b>	-26,291	-23.37

Table 8. Elasticities of consumption and growth to network costs

	<b>Consumption</b>	<b>Growth</b>
<b>Short-run Elasticity in %</b>	-0.063	-0.012
<b>Short-run Effect in MWh &amp; M€</b>	-62,731	-55.77
<b>Long-run Elasticity in %</b>	-0.051	-0.010
<b>Long-run Effect in MWh &amp; M€</b>	-51,209	-45.53

2013

- 2013/1, Sánchez-Vidal, M.; González-Val, R.; Viladecans-Marsal, E.: "Sequential city growth in the US: does age matter?"
- 2013/2, Hortas Rico, M.: "Sprawl, blight and the role of urban containment policies. Evidence from US cities"
- 2013/3, Lampón, J.F.; Cabanelas-Lorenzo, P.; Lago-Peñas, S.: "Why firms relocate their production overseas? The answer lies inside: corporate, logistic and technological determinants"
- 2013/4, Montolio, D.; Planells, S.: "Does tourism boost criminal activity? Evidence from a top touristic country"
- 2013/5, García-López, M.A.; Holl, A.; Viladecans-Marsal, E.: "Suburbanization and highways: when the Romans, the Bourbons and the first cars still shape Spanish cities"
- 2013/6, Bosch, N.; Espasa, M.; Montolio, D.: "Should large Spanish municipalities be financially compensated? Costs and benefits of being a capital/central municipality"
- 2013/7, Escardíbul, J.O.; Mora, T.: "Teacher gender and student performance in mathematics. Evidence from Catalonia"
- 2013/8, Arqué-Castells, P.; Viladecans-Marsal, E.: "Banking towards development: evidence from the Spanish banking expansion plan"
- 2013/9, Asensio, J.; Gómez-Lobo, A.; Matas, A.: "How effective are policies to reduce gasoline consumption? Evaluating a quasi-natural experiment in Spain"
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- 2013/11, Segarra, A.; García-Quevedo, J.; Teruel, M.: "Financial constraints and the failure of innovation projects"
- 2013/12, Jerrim, J.; Choi, A.: "The mathematics skills of school children: How does England compare to the high performing East Asian jurisdictions?"
- 2013/13, González-Val, R.; Tirado-Fabregat, D.A.; Viladecans-Marsal, E.: "Market potential and city growth: Spain 1860-1960"
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- 2013/15, Ahlfeldt, G.M.; Maennig, W.: "Homevoters vs. leasevoters: a spatial analysis of airport effects"
- 2013/16, Lampón, J.F.; Lago-Peñas, S.: "Factors behind international relocation and changes in production geography in the European automobile components industry"
- 2013/17, Guío, J.M.; Choi, A.: "Evolution of the school failure risk during the 2000 decade in Spain: analysis of Pisa results with a two-level logistic mode"
- 2013/18, Dahlby, B.; Rodden, J.: "A political economy model of the vertical fiscal gap and vertical fiscal imbalances in a federation"
- 2013/19, Acacia, F.; Cubel, M.: "Strategic voting and happiness"
- 2013/20, Hellerstein, J.K.; Kutzbach, M.J.; Neumark, D.: "Do labor market networks have an important spatial dimension?"
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- 2013/22, Lin, J.: "Regional resilience"
- 2013/23, Costa-Campi, M.T.; Duch-Brown, N.; García-Quevedo, J.: "R&D drivers and obstacles to innovation in the energy industry"
- 2013/24, Huisman, R.; Stradnic, V.; Westgaard, S.: "Renewable energy and electricity prices: indirect empirical evidence from hydro power"
- 2013/25, Dargaud, E.; Mantovani, A.; Reggiani, C.: "The fight against cartels: a transatlantic perspective"
- 2013/26, Lambertini, L.; Mantovani, A.: "Feedback equilibria in a dynamic renewable resource oligopoly: pre-emption, voracity and exhaustion"
- 2013/27, Feld, L.P.; Kalb, A.; Moessinger, M.D.; Osterloh, S.: "Sovereign bond market reactions to fiscal rules and no-bailout clauses – the Swiss experience"
- 2013/28, Hilber, C.A.L.; Vermeulen, W.: "The impact of supply constraints on house prices in England"
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- 2013/32, Saarimaa, T.; Tukiainen, J.: "Local representation and strategic voting: evidence from electoral boundary reforms"
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## 2014

- 2014/1, Montolio, D.; Planells-Struse, S.: "When police patrols matter. The effect of police proximity on citizens' crime risk perception"
- 2014/2, García-López, M.A.; Solé-Ollé, A.; Viladecans-Marsal, E.: "Do land use policies follow road construction?"
- 2014/3, Piolatto, A.; Rablen, M.D.: "Prospect theory and tax evasion: a reconsideration of the Yitzhaki puzzle"
- 2014/4, Cuberes, D.; González-Val, R.: "The effect of the Spanish Reconquest on Iberian Cities"
- 2014/5, Durán-Cabré, J.M.; Esteller-Moré, E.: "Tax professionals' view of the Spanish tax system: efficiency, equity and tax planning"
- 2014/6, Cubel, M.; Sanchez-Pages, S.: "Difference-form group contests"
- 2014/7, Del Rey, E.; Racionero, M.: "Choosing the type of income-contingent loan: risk-sharing versus risk-pooling"
- 2014/8, Torregrosa Hetland, S.: "A fiscal revolution? Progressivity in the Spanish tax system, 1960-1990"
- 2014/9, Piolatto, A.: "Itemised deductions: a device to reduce tax evasion"
- 2014/10, Costa, M.T.; García-Quevedo, J.; Segarra, A.: "Energy efficiency determinants: an empirical analysis of Spanish innovative firms"
- 2014/11, García-Quevedo, J.; Pellegrino, G.; Savona, M.: "Reviving demand-pull perspectives: the effect of demand uncertainty and stagnancy on R&D strategy"
- 2014/12, Calero, J.; Escardíbul, J.O.: "Barriers to non-formal professional training in Spain in periods of economic growth and crisis. An analysis with special attention to the effect of the previous human capital of workers"
- 2014/13, Cubel, M.; Sanchez-Pages, S.: "Gender differences and stereotypes in the beauty"
- 2014/14, Piolatto, A.; Schuett, F.: "Media competition and electoral politics"
- 2014/15, Montolio, D.; Trillas, F.; Trujillo-Baute, E.: "Regulatory environment and firm performance in EU telecommunications services"
- 2014/16, Lopez-Rodriguez, J.; Martinez, D.: "Beyond the R&D effects on innovation: the contribution of non-R&D activities to TFP growth in the EU"
- 2014/17, González-Val, R.: "Cross-sectional growth in US cities from 1990 to 2000"
- 2014/18, Vona, F.; Nicolli, F.: "Energy market liberalization and renewable energy policies in OECD countries"
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- 2014/20, Duro, J.A.; Teixidó-Figueras, J.; Padilla, E.: "The causal factors of international inequality in CO<sub>2</sub> emissions per capita: a regression-based inequality decomposition analysis"
- 2014/21, Fleten, S.E.; Huisman, R.; Kilic, M.; Pennings, E.; Westgaard, S.: "Electricity futures prices: time varying sensitivity to fundamentals"
- 2014/22, Afcha, S.; García-Quevedo, J.: "The impact of R&D subsidies on R&D employment composition"
- 2014/23, Mir-Artigues, P.; del Río, P.: "Combining tariffs, investment subsidies and soft loans in a renewable electricity deployment policy"
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- 2014/29, Teresa Costa, M.T.; Trujillo-Baute, E.: "Retail price effects of feed-in tariff regulation"
- 2014/30, Kilic, M.; Trujillo-Baute, E.: "The stabilizing effect of hydro reservoir levels on intraday power prices under wind forecast errors"
- 2014/31, Costa-Campi, M.T.; Duch-Brown, N.: "The diffusion of patented oil and gas technology with environmental uses: a forward patent citation analysis"
- 2014/32, Ramos, R.; Sanromá, E.; Simón, H.: "Public-private sector wage differentials by type of contract: evidence from Spain"
- 2014/33, Backus, P.; Esteller-Moré, A.: "Is income redistribution a form of insurance, a public good or both?"
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- 2014/35, Jerrim, J.; Choi, A.; Simancas Rodríguez, R.: "Two-sample two-stage least squares (TSTSLS) estimates of earnings mobility: how consistent are they?"
- 2014/36, Mantovani, A.; Tarola, O.; Vergari, C.: "Hedonic quality, social norms, and environmental campaigns"
- 2014/37, Ferraresi, M.; Galmarini, U.; Rizzo, L.: "Local infrastructures and externalities: Does the size matter?"
- 2014/38, Ferraresi, M.; Rizzo, L.; Zanardi, A.: "Policy outcomes of single and double-ballot elections"

## 2015

- 2015/1, Foremny, D.; Freier, R.; Moessinger, M.-D.; Yeter, M.:** "Overlapping political budget cycles in the legislative and the executive"
- 2015/2, Colombo, L.; Galmarini, U.:** "Optimality and distortionary lobbying: regulating tobacco consumption"
- 2015/3, Pellegrino, G.:** "Barriers to innovation: Can firm age help lower them?"
- 2015/4, Hémet, C.:** "Diversity and employment prospects: neighbors matter!"
- 2015/5, Cubel, M.; Sanchez-Pages, S.:** "An axiomatization of difference-form contest success functions"
- 2015/6, Choi, A.; Jerrim, J.:** "The use (and misuse) of Pisa in guiding policy reform: the case of Spain"
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- 2015/26, Moriconi, S.; Picard, P.M.; Zanaj, S.:** "Commodity taxation and regulatory competition"
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- 2015/33, Escardíbul, J.O.; Helmy, N.:** "Decentralisation and school autonomy impact on the quality of education: the case of two MENA countries"
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- 2015/36, Mediavilla, M.; Zancajo, A.:** "Is there real freedom of school choice? An analysis from Chile"
- 2015/37, Daniele, G.:** "Strike one to educate one hundred: organized crime, political selection and politicians' ability"
- 2015/38, González-Val, R.; Marcén, M.:** "Regional unemployment, marriage, and divorce"
- 2015/39, Foremny, D.; Jofre-Monseny, J.; Solé-Ollé, A.:** "'Hold that ghost': using notches to identify manipulation of population-based grants"
- 2015/40, Mancebón, M.J.; Ximénez-de-Embún, D.P.; Mediavilla, M.; Gómez-Sancho, J.M.:** "Does educational management model matter? New evidence for Spain by a quasiexperimental approach"
- 2015/41, Daniele, G.; Geys, B.:** "Exposing politicians' ties to criminal organizations: the effects of local government dissolutions on electoral outcomes in Southern Italian municipalities"
- 2015/42, Ooghe, E.:** "Wage policies, employment, and redistributive efficiency"

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**2016**

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- 2016/1, Galletta, S.:** "Law enforcement, municipal budgets and spillover effects: evidence from a quasi-experiment in Italy"
- 2016/2, Flatley, L.; Giulietti, M.; Grossi, L.; Trujillo-Baute, E.; Waterson, M.:** "Analysing the potential economic value of energy storage"
- 2016/3, Calero, J.; Murillo Huertas, I.P.; Raymond Bara, J.L.:** "Education, age and skills: an analysis using the PIAAC survey"
- 2016/4, Costa-Campi, M.T.; Daví-Arderius, D.; Trujillo-Baute, E.:** "The economic impact of electricity losses"
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- 2016/8, González-Val, R.:** "Historical urban growth in Europe (1300–1800)"
- 2016/9, Guio, J.; Choi, A.; Escardíbul, J.O.:** "Labor markets, academic performance and the risk of school dropout: evidence for Spain"
- 2016/10, Bianchini, S.; Pellegrino, G.; Tamagni, F.:** "Innovation strategies and firm growth"
- 2016/11, Jofre-Monseny, J.; Silva, J.I.; Vázquez-Grenno, J.:** "Local labor market effects of public employment"
- 2016/12, Sanchez-Vidal, M.:** "Small shops for sale! The effects of big-box openings on grocery stores"
- 2016/13, Costa-Campi, M.T.; García-Quevedo, J.; Martínez-Ros, E.:** "What are the determinants of investment in environmental R&D?"
- 2016/14, García-López, M.A.; Hémet, C.; Viladecans-Marsal, E.:** "Next train to the polycentric city: The effect of railroads on subcenter formation"
- 2016/15, Matas, A.; Raymond, J.L.; Dominguez, A.:** "Changes in fuel economy: An analysis of the Spanish car market"
- 2016/16, Leme, A.; Escardíbul, J.O.:** "The effect of a specialized versus a general upper secondary school curriculum on students' performance and inequality. A difference-in-differences cross country comparison"
- 2016/17, Scandurra, R.I.; Calero, J.:** "Modelling adult skills in OECD countries"
- 2016/18, Fernández-Gutiérrez, M.; Calero, J.:** "Leisure and education: insights from a time-use analysis"
- 2016/19, Del Rio, P.; Mir-Artigues, P.; Trujillo-Baute, E.:** "Analysing the impact of renewable energy regulation on retail electricity prices"
- 2016/20, Taltavull de la Paz, P.; Juárez, F.; Monllor, P.:** "Fuel Poverty: Evidence from housing perspective"
- 2016/21, Ferraresi, M.; Galmarini, U.; Rizzo, L.; Zanardi, A.:** "Switch towards tax centralization in Italy: A wake up for the local political budget cycle"
- 2016/22, Ferraresi, M.; Migali, G.; Nordi, F.; Rizzo, L.:** "Spatial interaction in local expenditures among Italian municipalities: evidence from Italy 2001-2011"
- 2016/23, Daví-Arderius, D.; Sanin, M.E.; Trujillo-Baute, E.:** "CO2 content of electricity losses"
- 2016/24, Arqué-Castells, P.; Viladecans-Marsal, E.:** "Banking the unbanked: Evidence from the Spanish banking expansion plan"
- 2016/25 Choi, Á.; Gil, M.; Mediavilla, M.; Valbuena, J.:** "The evolution of educational inequalities in Spain: Dynamic evidence from repeated cross-sections"
- 2016/26, Brutti, Z.:** "Cities drifting apart: Heterogeneous outcomes of decentralizing public education"
- 2016/27, Backus, P.; Cubel, M.; Guid, M.; Sánchez-Pages, S.; Lopez Manas, E.:** "Gender, competition and performance: evidence from real tournaments"
- 2016/28, Costa-Campi, M.T.; Duch-Brown, N.; García-Quevedo, J.:** "Innovation strategies of energy firms"
- 2016/29, Daniele, G.; Dipoppa, G.:** "Mafia, elections and violence against politicians"

**2016/30, Di Cosmo, V.; Malaguzzi Valeri, L.:** “Wind, storage, interconnection and the cost of electricity”

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**2017**

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**2017/1, González Pampillón, N.; Jofre-Monseny, J.; Viladecans-Marsal, E.:** "Can urban renewal policies reverse neighborhood ethnic dynamics?"

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